MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY CENTRAL LABORATORY MECHANICAL STUDY

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Hello -

We are pleased to present our comprehensive mechanical study of the Missouri Department of Transportation (MoDOT) Central Laboratory. This study aims to provide an in-depth analysis of the existing mechanical systems and recommended improvements.

The MoDOT Central Laboratory is a critical facility serving various functions essential to the operations of the department. The lab is equipped with several advanced mechanical systems designed to maintain optimal working conditions and ensure the safety and accuracy of lab operations.

Our findings and recommendations are detailed below in the report. We appreciate the opportunity to conduct this study and look forward to collaborating with MoDOT to achieve the best outcomes for the Central Laboratory.

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EXISTING MECHANICAL SYSTEM ANALYSIS

The MoDOT (Missouri Department of Transportation) Central Laboratory was built in 1997. The lab building consists of five (5) main areas: basement mechanical area, chemical lab, physical lab, geotechnical lab, and administration/support.

<u>Basement Mechanical Area</u>

The majority of the building is cooled by a central cooling plant. The central cooling plant of the lab consists of two water cooled chillers located in the basement, cooling towers on the roof, three condensing water pumps, two secondary loop pumps, and two primary loop pumps. This system is then piped to the existing air handlers and their cooling coils. The cooling plant has recently been replaced in other projects and will be outside of the scope of this study.

The building is heated entirely from a central heating plant. The plant outputs both steam and 180 deg F hydronic hot water. For steam, there are two, 250 horsepower Burnham, gas fired, boilers. These produce 8,625 lbs/hr (pounds per hour) of steam at a pressure of 15 psi (pounds per square inch). To create hot water, there are steam to hot water shell and tube heat exchangers. These heat exchangers can convert 7,200 lbs/hr to 700 gpm (gallons per minute) of 180-degree F. Any steam not used for creating hot water is piped to the air handling units. The hot water is then pumped from the mechanical room from two (2) 15 hp lead/lag pumps. The pumps move 450 gpm of hot water at 70 feet of head. These pumps are on VFDs (variable frequency drives) making this system a variable primary hot water heating system. The hot water is then pumped to air handlers and to FVBs (fan powered variable volume box) for their reheat coils.

Figure 1: Existing Steam Boilers

Figure 2: Shell and Tube Steam to Hot Water Heat Exchangers

The basement space is conditioned using two chilled water-cooled Liebert air handling units with three stages of electric reheat. There are also powered wall dampers that open to an area well and a ventilation fan that provides fresh air to the room. AHU-6 and AHU-7 are also located in this mechanical space. These units do not serve this space but are ducted to other areas of the building.

Chemical Lab

The chemical lab is located on the Northwest side of the building. The majority of the laboratory hoods located within the building are in this lab. The chemical lab is divided into nine (9) separate parts. They are as follows: cement lab, instrument lab, acid lab, asphalt lab, paint lab, flammable lab, asbestos lab, chemical storage, and workstation/office areas. MAU-1 (make up air unit) serves the instrument lab and the acid lab. MAU-2 serves the asphalt lab, asbestos lab, paint lab, and flammable lab. AHU-1 (air handling unit) serves all spaces listed above, except the cement lab.

MAU-1 is a variable speed, 100% outside air, air handling unit. This unit was made by Dunham-Bush in 1994. It was designed to supply 9,000 cfm (cubic feet per minute) of tempered make up air to the space. There is a 15 hp supply fan within the unit. It is powered by 460 V, 3 phase power. There is one (1) 504,900 BTUH (British thermal units per house) steam preheat coil, one (1) 461,000 BTUH chilled water-cooling coil, and one (1)

343,900 BTUH hot water reheat coil. A humidifier dispersion tube was added to the makeup air unit. Per conversations with MoDOT, the humidifier is obsolete. MAU-1 serves seven (7) CVBs (constant volume box). MAU-2 is a variable speed, 100% outside air, air handling unit. This unit was made by Dunham-Bush in 1994. It was designed to supply 28,000 cfm (cubic feet per minute) of tempered make up air to the space. There is a 40 hp supply fan within the unit. It is powered by 460 V, 3 phase power. There is one (1), 678,400 BTUH (British thermal units per house) steam preheat coil, one (1),557,700 BTUH chilled water-cooling coil, and one (1),151,800 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit, but again has been identified by MoDOT as obsolete. MAU-2 serves twenty (20) CVBs.

The make-up air unit system was designed to make up air to the lab that was exhausted from the space by the exhaust fans that are attached to the hoods within the space. When the exhaust fan is enabled, a constant volume box is to open. The air that is serving the constant volume boxes is supposed to be “room neutral” air. The make-up air unit serving the constant volume boxes should react to the boxes opening and closing by varying the speed of the fan to change the volumetric flow of the air and shall modulate the control valves on the preheat, cooling, and reheat coils to maintain a discharge air temperature of room neutral air.

AHU-1 is a variable speed air handling unit that recirculates air from the space. This unit was made by Dunham-Bush in 1994. It was designed to condition 9,500 cfm (cubic feet per minute) of recirculated air to the space. There is a 15 hp supply fan and a 5 hp return fan within the unit. It is powered by 460 V, 3 phase power. There is not a steam preheat coil within this unit. There is a 461,000 BTUH chilled water-cooling coil and a 343,900 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit, and as identified above, is obsolete. AHU-1 serves thirteen (13) VBs (variable volume box) and six (6) FVBs with reheat coils.

The air handling unit system was designed to condition the lab space and its air. The original control design was to be that of a typical variable air volume system. The AHU is designed to have an output of 55 deg F air. This is done through modulation of the control valves on the cooling coil and preheat coil. The supply fan then modulates its speed based on a duct static pressure reading and comparing it to the duct static pressure setpoint. The static pressure within a duct increases or decreases based on how open or closed the dampers are within the VBs and the FVBs. The VBs and FVBs modulate their primary air damper to maintain space temperature. The FVBs are parallel fan boxes, meaning the fan is not located within the main air stream. The fan modulates to allow a mixed air temperature from the box. There is also a hot water reheat coil at the FVB that is used to reheat the entering 55 deg F air to a higher desired temperature.

The cement lab is one of the few areas with strict humidity and temperature requirements. The space must stay between 68-79 deg F and stays around 50% RH (relative humidity) all year. The space is served by AHU-11 and AHU-12. These are package, DX (direct expansion) units. There is an electric duct humidifier that maintains humidity in the room. There is an electric unit heater located within the room to heat the space. There is also a dust collection system, DCS-2, that serves this space. As per conversations with MoDOT, this dust collection system is no longer required.

The hoods and their associated exhaust fans were designed to be constant volume. An operator is able to activate the hood, thus activating its exhaust fan. It is unknown when the variable speed controllers were added to the hoods that allowed the operator to change the speed of the exhaust fans. Within the chemical lab space, there are twenty-eight (28) hoods or source capture exhaust systems. There are four (4) room exhaust fans.

Figure 3: Typical Laboratory Exhaust Hood

Figure 4: Lab Exhaust Controller Mounted on Hood

Figure 5: Asbestos Testing Lab

<u>Physical Lab</u>

The physical lab is the largest area of this building. There are four major areas in this lab: Aggregate lab, bituminous lab, concrete mixing lab, and the general materials. Offices and meeting spaces are intertwined throughout the lab. The aggregate lab is the largest of the three. It encompasses a large portion of the Southeast corner and wing of the lab. AHU-7, located in the basement, serves the concrete mixing lab. MAU-4 also serves the concrete mixing area and the hoods located within the space. AHU-3 serves the aggregate lab on the southernmost side of the building. AHU-2 serves the bituminous and general materials. MAU-3 serves the bituminous and general materials. AHU-9 serves the Southeastern most corner of the building where the freeze/thaw room is located. AHU-8 no longer exists. The space that it used to serve has been transitioned into a 100% humidity room. The room is tempered by changing the temperature of the mist supplied into the room. Aggregate and cement mixing are on one dust collection system, DCS-1. The system is original to the building. Bituminous also has a dust collection system. It is shared with the soil area in the geotechnical area.

MAU-4 is a variable speed, 100% outside air, air handling unit. This unit was made by Dunham-Bush in 1994. It was designed to supply 4,000 cfm (cubic feet per minute) of tempered make up air to the space. There is a 5 hp supply fan within the unit. It is powered by 460 V, 3 phase power. There is one (1) 221,200 BTUH (British thermal units per house) steam preheat coil, one (1) 206,600 BTUH chilled water-cooling coil, and one (1)

85,400 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit. Per conversations with MoDOT, the humidifier is obsolete. MAU-4 serves two (2) CVBs (constant volume box).

MAU-3 is a variable speed, 100% outside air, air handling unit. This unit was made by Dunham-Bush in 1994. It was designed to supply 11,000 cfm (cubic feet per minute) of tempered make up air to the space. There is a 15 hp supply fan within the unit. It is powered by 460 V, 3 phase power. There is one (1) 596,000 BTUH (British thermal units per house) steam preheat coil, one (1) 573,800 BTUH chilled water-cooling coil, and one (1) 417,700 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit and identified as obsolete per MoDOT. MAU-3 serves six (6) CVBs (constant volume box).

AHU-3 is a variable speed air handling unit that recirculates air from the space. This unit was made by Dunham-Bush in 1994. It was designed to condition 8,300 cfm (cubic feet per minute) of recirculation air to the space. There is a 10 hp supply fan and a 5 hp return fan within the unit. It is powered by 460 V, 3 phase power. There is not a steam preheat coil within this unit. There is one (1) 277,700 BTUH chilled water-cooling coil and one (1) 187,100 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit and is obsolete per MoDOT. AHU-3 serves nine (9) VBs (variable volume box) and five (5) FVBs with reheat coils.
AHU-2 is a variable speed air handling unit that recirculates air from the space. This unit was made by Dunham-Bush in 1994. It was designed to condition 8,185 cfm (cubic feet per minute) of recirculation air to the space. There is a 10 hp supply fan and a 5 hp return fan within the unit. It is powered by 460 V, 3 phase power. There is not a steam preheat coil within this unit. There is one (1) 258,000 BTUH chilled water-cooling coil and one (1) 186,200 BTUH hot water reheat coil. Again, a humidifier dispersion tube was added to the make-up air unit and is obsolete per MoDOT. AHU-2 serves twelve (12) VBs.

AHU-9 is a constant volume, cooling only air handler. It is a DX type air handler that is there as a cooling requirement for the existing freeze/thaw room.

Within the physical lab there are thirteen (13) exhaust fans. Bituminous has four (4), aggregate has four (4), and cement mixing has two (2). The fans within bituminous, aggregate, and cement are hooded exhaust.

The controls for the exhaust fans, the MAUs, and the AHU's match that of the chemical lab.

Figure 6: New Freeze/Thaw Machine

Geotechnical Lab

The geotechnical lab is located in the Southwest area of the building. There are three main areas of this lab: the soil lab, soil testing lab, and offices. AHU-4 serves the geotechnical offices and soil lab. Soil testing is served by AHU-3. There is a moisture room located within the soil lab that is served by AHU-10.

AHU-4 is a variable speed air handling unit that recirculates air from the space. This unit was made by Dunham-Bush in 1994. It was designed to condition 5,670 cfm (cubic feet per minute) of recirculation air to the space. There is a 7.5 hp supply fan and a 5 hp return fan within the unit. It is powered by 460 V, 3 phase power. There is not a steam preheat coil within this unit. There is one (1) 199,300 BTUH chilled water-cooling coil and one (1) 127,400 BTUH hot water reheat coil. A humidifier dispersion tube was added to the make-up air unit, and is obsolete per MoDOT. AHU-4 serves four (4) VBs (variable volume box) and five (5) FVBs with reheat coils.

AHU-10 is a constant volume, DX cooling only unit. It serves a space that has its own dedicated humidifier.

There are no exhaust fans in the geotechnical area. There is a shared dust collection system that serves the soil testing area as well as the bituminous area.

Administration/Support

Administration/Support is an encompassing term that incorporates all items not discussed above. This would include hallways, restrooms, the two-story offices on the Northeast portion of the building, and receiving area. AHU-5 serves the hallway corridors in the building as well as first floor restroom and office spaces. AHU-6 serves the Northeastern most offices on the first and second floor.

AHU-5 is a constant speed air handling unit that recirculates air from the space. This unit was made by Dunham-Bush in 1994. It was designed to condition 9,000 cfm (cubic feet per minute) of recirculation air to the space. There is a 10 hp supply fan and a 5 hp variable speed return fan within the unit. It is powered by 460 V, 3 phase power. There is one (1)a 380,100 BTUH (British thermal units per house) steam preheat coil, one (1)a 494,600 BTUH chilled water-cooling coil, and one (1)a 655,900 BTUH hot water reheat coil. There is also an electric duct heater within the supply ductwork below the roof. A humidifier dispersion tube was added to the make-up air unit, but, as per conversations with MoDOT, is obsolete.

AHU-6 is a variable speed, built up air handling unit that recirculates air from the space. It was designed to condition 11,500 cfm (cubic feet per minute) of recirculation air to the space. AHU-6 has an internal supply fan and an external return. There is only one (1)a cooling coil and one (1) hot water reheat coil. AHU-6 serves seven (7) VBs and twelve (12) FVBs with reheat coils.

There are four (4) general exhaust fans that serve the bathrooms and storage rooms within the administration/support areas. These are activated by an occupied signal sent via the BAS (building automation system).

Figure 7: Picture of AHU-6

General

The entire building is on a Johnson Controls Metasys system. The controls have recently (2021/22) been upgraded costing the state $275k. Johnson completed an analysis that was reviewed prior to the writing of this report.

M/E1 conducted interviews with department heads as well as employees in each department. Most long-term employees pointed to problems starting to occur around five (5) years ago.

There is a central vacuum system in the building. After discussing the system with employees, there was a consensus that the central vacuum system is no longer in use.

DEFICIENCIES IN THE CURRENT MECHANICAL SYSTEM

During this study, the goal of M/E1 was to find and highlight the problems that occur throughout the building. While on site, interviews were conducted with department leaders and other employees. All departments had their opportunities to discuss their issues and problems with the current system. Items were also observed on these walkthroughs that could be potential causes of these problems.

Basement Mechanical Area

Within the basement there are only a few identified issues. The main issue identified was that the steam boilers of the heating system were operating on low fire most of the year. This was determined through discussions with MoDOT's facility associates. Boilers that fire on low are not firing in their most efficient operation. This also means that the boilers for the heating system are not utilized to their fullest capacity.

The steam to hot water shell and tube heat exchangers and the hot water pumps are aging. They are original to the building. With their age, they are moving further away from their expected useful life expectancy. Using steam to create hot water is not the most efficient way to create hot water. New technologies have allowed the growth of condensing boilers that are a more efficient way of producing heating hot water. The boiler system is also being shutdown during the summer months. This is exacerbating the temperature control problems because there is no reheat in any air handlers, make up air units, or FVBs. This causes the spaces to overcool.

AHU-6 and AHU-7 are original to the building. There were not any observable performance problems with these existing units, however, these units are original to the building. The cabinets are showing signs of age as well as inefficient fan motors that are not up to current motor efficiency standards. The cabinet failing and fan motors being of an older generation mean that the units are not running the most efficiently that they could be due to air leakage and wasted power at the fan motors.

The final issue that was noted during M/E1's visits to the site was the failing motorized relief damper on the Eastern side of the mechanical room. The actuators on the dampers do not fully operate as they once did. The dampers are original to the building and the aging actuators struggle to fully open and close the dampers.

Chemical Lab

The chemical lab is the area where the majority of the problems within the building occur. This is due to the complexity of the controls and system that is needed to properly condition and pressurize this area. There are also different areas that require different levels of care and performance. For instance, the acid lab is more critical than the offices located within the same area.

The first issue that was discussed is the pressure swings within the space causing the doors of the lab to either be sucked closed or blown open. This is a potential life safety problem in that some rooms need to remain negative to mitigate the transmission of chemical fumes from lab areas to non-chemical areas. There is also the problem that doors being sucked closed or blown open can swing into people or block egress. The acid lab should remain negative to the spaces surrounding it. The asbestos lab should remain negative to the spaces around it. Flammable paints should remain negative to the spaces around it. The asphalt lab should remain negative to the corridor throughout the building, but positive to the spaces noted above. The acid storage should also remain negative to the spaces that surround it. There is no exhaust currently in this room. This problem is exacerbated by not having pressure monitoring systems located above the doors.

The second major issue that was noted was the temperature control within all spaces in the chemical lab. Note, this does not including the cement lab as that is on its own separate system. The temperature could swing wildly from day to day. On site discussions with employees identified certain days the lab would be 52 deg F while other days it would be 90 deg F. While this is not a life safety concern, this is a comfort issue. The cause of this is due to the age of the system, the initial design of the system, and the control of the system. Both problems noted above, pressure and temperature, are caused by MAU-1, AHU-1, MAU-2, the exhaust fans in the space, the VBs/FVBs/CVBs, and the controls of all systems noted.

MAU-1 and MAU-2 have problems when the system requires low make up air as the turndown on the supply fan is not enough. Most VFD's can reduce the fan speed of a motor down to 30%. The initial intended control issue of the make up air system is that when an exhaust fan serving a hood is engaged, a constant volume box is kicked on to make up that air. If only a handful of certain exhaust fan's are engaged, the number of CVBs that are opened are minimal. The supply fan of the make up air unit cannot back off the supply flow due to limitations of the VFD. This means that the room will be positive as more air will be supplied to the space than is exhausted through the lab exhaust hoods. On the flip side, the CVBs that are associated with the hoods are not supplying equal air to that being exhausted by the exhaust fan. As more exhaust fans engage, there becomes a greater difference between the volumetric flow of the exhausted air versus supplied air to the room. This will increase the negative pressure in the room. There is no way to control the pressure differential from room to room. AHU-1 is also bringing outside air into the space for code required ventilation air causing even more problems for the pressurization of the system. The last item is that MAU-1 and MAU-2 both serve connecting rooms This means that MAU-1 system and MAU-2 system could be fighting one another as one tries to supply less air and one tries to supply more air. Controls work has been completed to try and band aid the system, but this can cause more problems as the band aid locks the operation of the units based on conditions at that moment. When the conditions change, the band aid no longer works as the operating conditions have changed.

As for the temperature of the lab, this problem is due to the design and control of AHU-1 and it's system. As noted in the background section, the AHU-1 is a VAV (variable air volume) system. This means that AHU-1 supplies 55 deg F air to the system year round. This then goes to the VBs and FVBs. This is where the problem lies: the VBs are cooling only boxes and the FVBs have a hot water reheat coil in them. During the heating season, the AHU-1 will be putting out cool air and supplying it to the duct distribution system. The only heating within the space is found at the FVBs. This could be a problem for a couple of reasons. The FVBs and their reheat are not sized correctly to properly heat the space, or the VBs are not "pinching back" to zero (0) cfm during the heating mode causing the VBs and FVBs to fight one another where the VBs are trying to cool the space whereas the FVBs are trying to cool the space at the same time.

Outside of the two major problems in this area, there were a handful of minor problems. These are as follows:

1. Poor air distribution within rooms
2. The exterior door in the instrument lab does not seal properly
3. The cement lab has condensation drip down the window during the winter as well as heating problems
4. Hood controllers are manually set by operators
5. There is no flow measuring device at each hood
6. MAUs and AHU-1 have incredibly tight preheat, cooling, and reheat coils that prevent proper maintenance.

The poor airflow in the lab is due to the choice of the diffusers that were initially installed as well as the use of auxiliary air lab hoods. The issue with the four way diffusers is that the throw of the air interferes with the capture of the air through the hoods. This existing condition was also blowing papers on the floor, causing uncomfortable drafts within the lab, and impacted lab equipment that needed fine measurements. The auxiliary hoods are hoods where the make up air is delivered to the hood directly. This air caused problems within the hoods themselves. Burner's and their flames would be blown out due to the airflow into the hood. Instruments would also be impacted by this as well. As per ASHRAE and their lab design guide, the best choice for distributing air within a lab space is to use low velocity diffusers. Low velocity diffusers will mitigate all the problems noted above.

The door in the instrument lab does not seal properly. During the winter, condensate can be found on surfaces near the door. This can cause deterioration of materials and create organic growth that can be detrimental to occupants. It also makes working on items by the door uncomfortable as the temperature is below an acceptable level for human comfort.

The cement lab is one of the only areas of the lab that has a working humidifier. This means that during the winter, when the windows get cold, condensation occurs on the face of the window. The air distribution as well as the system within the room does not allow for proper airflow and heating along the face of the windows.

At each hood is a system that allows the operator to change the speed of the fan that is serving the hood. This, in combination with the lack of flow measuring at the hoods, causes issues in that there is no way for the BAS (building automation system) to know what the volumetric flow of the hood is. This means it is impossible for the CVBs to properly make up the airflow to the space. Giving the operator's power to change the airflow also means that the hoods are not capturing their contaminants properly as they may not be having the correct face velocity to properly ventilate.

The last discussion item in the chemical lab is that the coils of the AHU and the MAUs are tight meaning proper maintenance of the coils cannot be performed. This could be a cause for poorer performance of the AHU and MAUs. This is consistent within all MAUs and AHUs 1 through 7.

Figure 8: Preheat, Cooling, and Reheat Stacked in an Air Handler

Figure 9: Roof Above Asphalt Lab. MAU-2 Shown

Figure 10: Exhaust Fans Above Instrumentation Lab

Figure 11: Laboratory Hood #9 with Example of Poor Air Distribution Device Above

Figure 12: Example of Four Way Diffusers Placed Poorly

Figure 13: Example of Auxillary Hood Supply Being Blanked Off

Physical Lab

The physical lab has many of the same problems as noted above in the chemical lab area. The bituminous lab, general materials, and the two areas with hoods in the cement mixing area have pressurization issues. All of these spaces are served by both AHUs and MAUs with the same control set-up as described above. The reasons as to why the pressures between spaces are not being kept are due to those controls. Aggregate and cement mixing have the same problems as that of the chemical lab when it comes to temperature control as the systems are similar to one another. Bituminous and general material lab are an independent issue.

The bituminous and general material lab are on an AHU that serves only VBs. These VBs do not have reheat. This means that all heating for this space would be through AHU-2. However, AHU-2 is a VAV type unit meaning that there is 55 deg F air being supplied to the space. This means that, as per the original controls, when in the dead of winter, there is no heat that is to be supplied to these spaces. This was temporarily fixed by the control's contractor by changing the discharge air temperature of the unit. This leads to overheating of some spaces as the VBs are controlled to open when cooling is needed meaning that as the space heats up, the VBs open to "cool" the space, but they are supplying hot air, meaning the space heats up more. It's a cyclical reaction that causes spaces to overheat, but, if not corrected, spaces will become overcooled.

The dust collection system is shared between aggregate and cement mixing. This means that both parties have stop and start buttons. This has lead to some occurrences where one lab turns off the system causing the other lab to start filling with dust. This has been helped with proper training of staff, but, with the dust possibly containing silica dust, this could create a life safety issue. It was also noted that the dust collection system is starting to struggle with suction. It is not pulling as much as it once was.

Instruments within the aggregate lab were noted to have started to rust. There have been days where the RH record is 75%. This could be from a multitude, or combination, of reasons. These include, but are not limited to: improper dehumidification of the supply air to the building, infiltration of outside air through the envelope of the building, infiltration of outside air through disabled exhaust fans, or infiltration from the receiving area into the aggregate area through the non-sealing doors.

In the cement mixing lab, there are two hoods. When the hoods are not in use, cold air has been noted to fall down within the space and create a cold and uncomfortable environment.

The receiving office wall backs up to the freezer. This has caused condensation to form in between the walls. This caused the condensate to damage the drywall found on the back wall of the closet in the receiving office. Again, condensate can damage materials and may cause organic growth that are problematic to occupant health.

Geotechnical Lab

The geotechnical lab had the least noted problems during our onsite review. There were minor complaints with the employees and director of this area. Most issues identified were comfort related items. This area is served by a single AHU, AHU-4. It does have the same system as that of the chemical and physical lab AHUs, however, this is the only system serving the space. This makes the control of space less complicated.

There are some air distribution problems. There are slots that are dumping air directly onto occupant's heads. There are some diffusers that are causing noises within offices due to high air velocities. The windows within the space have poor seals letting air enter in through the perimeter of the window. Lastly, AHU-4, when turning on, can create a loud noise that sounds like a jet engine that can be irritating to employees.

Administration/Support

Within the administration space of the Northeastern area, the primary complaint is that there is poor temperature control. This can be due to improper zoning due to walls that have been added post construction, poor control of the system, or lagging performance of the existing reheat coils. The system that serves this space is a VAV type system from AHU-6. It is controlled the same way as the other AHUs throughout the building.

As per the employees, the restrooms on the first floor are cold during the winter. These restrooms are served by AHU-5 and are located within the interior of the building (not on an exterior wall). The reason for the cold temperature may be that the exhaust fan is not running as intended. This allows colder air to fall into the space if there is no backdraft damper installed.

PROPOSED UPGRADES & PRIORITIES

Proposed changes will be identified for each section of the building. The sections and their proposed changes will be M/E1's order of priority to address. The expected phasing and estimated funds for construction needed will be broken down in the below sections of this document. The purpose of this is to allow MoDOT to select and choose different upgrades that may be appropriate based on funding availability. The general item that will be consistent throughout all of these recommendations is that there needs to be an overhaul to the controls system and its recommended, due to high heat load from equipment, that the cooling system be ran year-round. The controls and sequences for many of these systems need to be rebuilt from the ground up. The cooling system is needed to provide adequate temperature control to the space.

Chemical Lab – Temperature, Air Distribution, and Pressurization

It is the belief of M/E1 that the temperature, air distribution, and pressure problems associated with the chemical lab are the most critical deficiencies that need to be fixed. When talking with the managers at the lab, decreasing the amount of down time for construction was a priority. Due to this note, option 1 may be the only feasible option. However, option 2 is presented as the ideal way that the lab space would be conditioned. If a lab was being constructed from the ground up, this is the way the mechanical system would be designed for that space. This option can be posed as a gut of the existing lab mechanical system.

Option 1:

This option will be a direct replacement of AHU-1, MAU-1, MAU-2 and all exhaust fans associated with the lab. The fan powered VAV boxes as well as the VBs would need to be replaced, but they would not be a direct replacement. This will be the least invasive option as there will be minimal ductwork changes, however, this is the least energy efficient option.

AHU-1 will be replaced with a like for like unit to the one described previously, minus the humidifier. It will be a fully custom unit with both variable speed supply and return fans. The unit will be designed to sit on the existing curb. The cooling and reheat coils will be spaced further apart to allow for proper maintenance. It will be controlled as a VAV type unit, however, the outside airflow will be set to zero (0).) cfm unless economizing is needed. This will help control the amount of ventilation air entering the space. The unit will deliver 55 deg F to the existing supply air duct. Supply air temperature setpoint shall also reset based on outside air temperature. The high reset temperature shall be 65 deg F when the outside air is 30 deg F or less. The supply fan will modulate the fan speed based on duct static pressure. A duct static pressure reset will be implemented into the controls to allow the fan to slow down during periods of low load. This is an energy saving measure. All control valves will be replaced with pressure independent control valves.

Downstream of AHU-1, new FVBs will be installed in place of the existing fan powered variable volume boxes. These will also have a hot water reheat coil. The existing VBs, will be replaced with hot water reheat variable air volume boxes. New hot water piping will need to be extended over from the central hot water loop to the new

VBs. The flow at the VBs and FVBs will be controlled by modulating two way valves. New balancing valves will also be installed. Both the new FVBs and VBs can then heat the space. If two boxes serve communicating spaces, they should be twinned on one thermostat. This eliminates the possibility of them fighting with each other. (i.e. one trying to cool the space while one tries to heat the space) This also adds more heat to the space. Using this system, there should be a more consistent temperature within the space.

MAU-1 and MAU-2 will also be replaced with an almost like for like unit, minus the humidifier. The other difference being that the cooling coil would ensure that the incoming outside air would be cooled down to at least 55 deg F to ensure that the incoming air is properly dehumidified. The unit will then modulate the reheat coil to maintain "room neutral" air. The coils will also be spaced apart to allow proper maintenance. A duct flow measuring traverse will be installed to measure the volumetric flow of the fan. The VFD of the supply fan will modulate to maintain the cfm setpoint as determined by the sum of the volumetric flow setpoints of the constant volume boxes. All new control valves and steam traps will be replaced. Control valves shall be of the pressure independent type.

All the exhaust fans will be replaced. Emergency exhaust fans will still be powered by a button on the wall. Strobes and horns will be attached to this button as well. The exhaust fan shall be constant speed and will manually need to be reset. General exhaust fans located in this area shall be replaced with for like kind and shall be on an occupied/unoccupied scheduled. Any laboratory exhaust hoods will get a new fume hood control system. This will measure the sash height, allowing the operator to change sash height as needed, and correlate that to required volumetric flow rate for safe operation. Volumetric flow measuring will be added to the connecting ductwork above the hood. This information will be sent to the BAS. The BAS will send a signal to the associated exhaust fan's VFD. The VFD will modulate to maintain the volumetric flowrate setpoint through the hood. Select exhaust fans and hoods will be always on via the BAS. This is to help to mitigate the problem of minimal turn down from MAU-1 and MAU-2. If some exhaust fans are always on, the space cannot become over pressurized. It will also ensure that there is at least 6 air changes per hour, as per the ASHRAE Lab Design Guide.

All the constant volume boxes shall be replaced. New pressure sensors across doors between rooms shall be installed to measure the pressure difference between spaces. See Appendix 03 for the pressure relationship drawing. The constant volume boxes shall be tied to their respective exhaust fan. All the CVBs within a room shall have a % offset as determined by the BAS. This % offset setpoint will modulate based on the pressure difference from the room to the next. For example, if the pressure needs to be more negative, the offset changes from 1.5% to 1.6%, and vice versa for more positive. This will give better control of the pressure between the spaces.

There will be two items added that are currently not there today. The first is on the MAU-1 system. A new CVB will be added to supply fresh, room temperature air to the office spaces. This shall be a constant volume during occupied periods. During unoccupied periods, the box shall close. This box is being added because AHU-1 is no longer supplying fresh air to the space. The second change is that an exhaust fan and a CVB in the MAU-2 needs to be added to the acid storage room. The exhaust fan shall exhaust at a rate of 2 cfm/sqft. The new CVB will supply at the % offset as described above.

The last item of this change would be to change the air devices within the lab spaces. As discussed above, the four way diffusers are a problem. Ductwork will need to be extended away from hoods and intakes. The diffusers then need to replaced with a low flow diffuser type. The preferred diffuser type is a radial flow diffuser. This can be seen below. This type of diffuser has a short throw length, meaning it will be easy to get to the 50 feet per minute at the hood intakes which is the recommended air speed from the ASHRAE Lab Design Guide.

Figure 14: Radial Diffuser

<u>Option 2:</u>

As stated previously, this option would greatly impact the chemical lab as it would cause long term downtime within the lab space itself. The work would be invasive render spaces unoccupiable. This change would have the most upfront cost. The benefits of this is system is that it would be more efficient, easier to control, and would meet current laboratory standards.

Starting with the demolition of items, the air handler that serves the space would be demolished. The ductwork that is connected to the air handler would also be demolished. All VBs and FVBs would be demolished as well. The recirculation air handling system would be removed entirely. The curb for the air handler shall remain. Exhaust fans within the instrument lab, acid lab, asphalt lab, and the paint lab that serve hoods and their connected ductwork would be demolished as well. The roof would need to be patched where the duct penetrations come through. The MAUs would also need to be demolished, however, the main ductwork for these units can stay. The CVBs and their diffusers would need to be removed as well. Select hoods that are past their useful life span would also need to be removed.

To start new work, it is important that the MAUs that will serve the chemical labs do not have spaces that communicate with one another. It is better and easier to control if airflow does not move from a space that MAU-1 serves to a space that MAU-2 serves. To combat this, it is recommended that walls be built around the work station area. Gasketed doors will be installed within the walls, but walls need to be airtight.

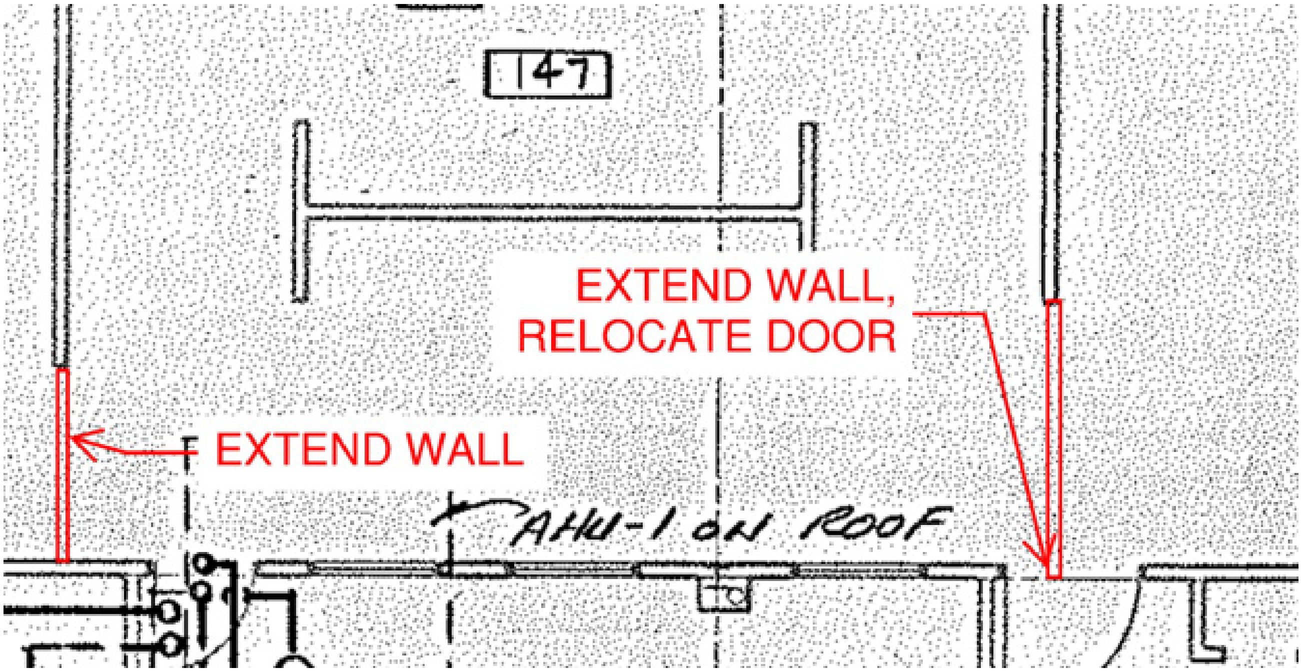


Figure 15: New Walls to Separate the Areas Served by MAU-1 and MAU-2

The hooded exhaust system will also change to be brought up to new lab standards. New hoods will be installed in place of the demolished hoods. New hood controllers would be installed on existing hoods that were deemed in good condition. The exhaust ducts for each hood would be connected to a fast acting, lab grade air valve. These valves change the volumetric flow rate at the hood based on sash height changes. They react fast to changes in sash height to ensure operator safety at the hood. These valves will then be connected to a new, roof mounted laboratory exhaust fan. The new exhaust fan will operate on a VFD to modulate it's speed. This will help save energy on times of low demand. Exhaust fans 9, 10, and 27 will remain on their own dedicated exhaust fan. This is because 9 and 10 are acid exhaust fans and 27 is serving the asbestos room. All other hood exhaust will be connected via air valves based on the make up air unit that serves the space. (i.e. all hooded exhaust in instrumentation and acid, outside of 9 and 10, will be on one exhaust fan connect with air valves).

Figure 16: Example of a Laboratory Exhaust Air Valve

Make up air and general conditioning of the space will be done through the use of the make up air units. MAU-1 and MAU-2 will now both be used to maintain make up air and space temperature. To do this, MAU-1 and MAU-2 will only have a preheat coil and chilled water coil. They will be pulling in 100% outside air, however, that air will be pretreated via a fixed plate ERV (energy recovery ventilator). That will be discussed below. The MAUs will be providing 55 deg F to the supply duct. The MAU's supply fan will modulate based on a duct static pressure. Both the supply temperature and duct static pressure setpoint shall be on a setpoint reset loop. The minimum flow for the MAUs shall be set to six (6) air changes per hour based on lab space served as per ASHRAE's laboratory design standards.

Downstream of the MAUs, new hot water reheat variable air volume boxes will be installed. These boxes will control the conditioning of the space. They will modulate their airflow damper from their minimum setpoint to their maximum airflow setpoint. Hot water reheat coils would be installed with the boxes. The control valve will modulate the flow of water through the coil to control the discharge temperature of the air based on the room temperature and the room temperature setpoint. The minimum airflow setpoint on these boxes serving the space would be equal to six (6) air changes per hour for each lab space.

Pressurization control of the space will be controlled via an exhaust variable air volume system connected to the ERVs. New, exhaust air VAVs will be installed into each space. New space pressurization sensors will be installed across each door to measure the differential pressure from space to space. The exhaust VAVs will modulate their damper to maintain the space pressurization setpoint. Notice during times of high lab hood usage, the flow through the exhaust air VAV will be lower. All exhaust air VAVs on one system will be attached via a central ductwork system. That will be connected into the ERV.

Each MAU will have its own, dedicated ERV. The ERVs will sit on the curb of the demolished AHU-1. The ERVs will have only an exhaust fan on a VFD. The VFD will be modulate the speed of exhaust fan to maintain the static duct pressure setpoint within the exhaust duct. This shall be set on a loop to reset the setpoint based on exhaust VAV damper position. This exhaust air shall go through the fixed plate heat exchanger and pre-condition the incoming outside air. That air will be directly ducted on the roof to the intake of the MAUs. The ERVs shall have a bypass to allow for defrosting of the fixed plate heat exchanger in colder months. Including the ERV will help increase energy efficiencies of the lab. Multiple pieces of equipment that need to be maintained are also being removed from the building.

For distribution of supply air into the space low velocity diffusers should be used. The radial ones shown in option 1 are good choices to deliver air to the space.

Bituminous and General Material Lab – Temperature, Air Distribution, and Pressurization

The second area that has deficient mechanical systems is the Bituminous and General Material labs. This is due to the same problems as listed in the chemical lab section, however, due to the nature of the materials tested in this area, it is not as critical to fix. The fix is similar to that of the chemical lab, as the systems are relatively the same.

AHU-2 will be replaced with a like for like unit to the one described previously, minus the humidifier. It will be a fully custom unit with both variable speed supply and return fans. The unit will be designed to sit on the existing curb. The cooling and reheat coils will be spaced further apart to allow for proper maintenance. It will be controlled as a VAV type unit, however, the outside airflow will be set to zero (0) cfm. This will help control the amount of ventilation air entering the space. The unit will deliver 55 deg F to the existing supply air duct. Supply air temperature setpoint shall also reset based on outside air temperature. The high reset temperature shall be 65 deg F when the outside air is 30 deg F or less. The supply fan will modulate the fan speed based on duct static pressure. A duct static pressure reset will be implemented into the controls to allow the fan to slow down during periods of low load. This is an energy saving measure. All control valves will be replaced with pressure independent control valves.

Downstream of AHU-2, the existing VBs will be replaced with hot water reheat variable air volume boxes. New hot water piping will need to be extended over from the central hot water loop to the new VBs. The flow at the VBs will be controlled by modulating two way valves. New balancing valves will also be installed. The new VBs can then heat the space, something they cannot do today. If two boxes serve communicating spaces, they should be twinned on one thermostat. This eliminates the possibility of them fighting with each other. (i.e. one trying to cool the space while one tries to heat the space) Using this system, there should be a more consistent temperature within the space.

MAU-3 will also be replaced with an almost like for like unit, minus the humidifier. The other difference being that the cooling coil will ensure that the incoming, outside air will be cooled down to at least 55 deg F to ensure that the fresh air is properly dehumidified. The unit will then modulate the reheat coil to maintain "room neutral" air. The coils will also be spaced apart to allow proper maintenance. A duct flow measuring traverse will be installed to measure the volumetric flow of the fan. The VFD of the supply fan will modulate to maintain the cfm setpoint as determined by the sum of the volumetric flow setpoints of the constant volume boxes. All new control valves and steam traps will be replaced. Control valves shall be of the pressure independent type.

All the exhaust fans will be replaced. Any laboratory exhaust hoods will get a new fume hood control system. This will measure the sash height, allowing the operator to change sash height as needed, and correlate that to required volumetric flow rate for safe operation. Volumetric flow measuring will be added to the connecting ductwork above the hood. This information will be sent to the BAS. The BAS will send a signal to the associated exhaust fan's VFD. The VFD will modulate to maintain the volumetric flowrate setpoint through the hood. Select exhaust fans and hoods will be always on via the BAS. This is to help to mitigate the problem of minimal turn down from the make up air unit. If some exhaust fans are always on, the space cannot become over pressurized. It will also ensure that there is at least 6 air changes per hour, as per the ASHRAE Lab Design Guide.

All the constant volume boxes shall be replaced. New pressure sensors across doors between rooms shall be installed to measure the pressure difference between spaces. See Appendix 03 for the pressure relationship drawing. The constant volume boxes shall be tied to their respective exhaust fan. All the CVBs within a room shall have a % offset as determined by the BAS. This % offset setpoint will modulate based on the pressure difference from the room to the next. For example, if the pressure needs to be more negative, the offset changes from 1.5% to 1.6%, and vice versa for more positive. This will give better control of the pressure between the spaces. The allow better capture of the items into hoods, low velocity diffusers, like the radial diffuser shown above, should be installed in place of the four way diffusers in places where the ductwork is near any source capture items. This will help ventilate the fumes and exhaust that should be exhausted from the space.

Cement Mixing and Aggregate – Dust Collection System Upgrades

The problems with the dust collection system between these two labs pose potential health risks. There is silica dust in some of the products that are tested in this facility. It is imperative to get that away from the employees.

The dust collection system is original to the building. It is recommended to be replaced. It is also recommended that the system be upsized as more items and connections have been put on this system than originally designed. As per conversations with employees, the system does not pull the dust away as it once did.

Another item that needs to be updated is the safety of the on/off system that is implemented today. Currently, two separate labs can turn the system off and on at will. This means that aggregate could turn the system off while cement mixing is using the system. Interlocks on the system need to be implemented to not allow the system to shutdown when either party is using the system. This will ensure that the dust needed to get captured, gets captured.

M/E1 recommends adding particulate air cleaner with bag filters in places where dust is prevalent. This will filter the air of any dust, collecting it within a room circulating system. It will help create better air quality in places where there are high levels of dust. For reference, below is a CamFil horizontal particulate air filter with bag filters.

Figure 17: Horizontal Particulate Air Filter with Bag Filters

Replacement and Upgrade of the Building Heating System

It is assumed that the above upgrades have been selected prior to this option. If that is not the case, some numbers below may be different than actual. To upgrade the heating system, there are, in M/E1's opinion, three choices. It should be noted that in all of these choices, the heating system shall stay on year-round to provide reheat when needed to all of the spaces. The first choice is to separate the steam generation system with the hot water generation system by removing the shell and tube heat exchangers and replacing them with condensing gas fire boilers. The second choice is to replace the existing system and upsize equipment on the hot water side to accommodate the new reheat coils. The final choice is that the steam system be removed. Due to the invasiveness of work, M/E1 does not recommend this choice if the building cannot be shutdown for longer periods of time.

Option 1:

In this option, both the steam and hot water system shall remain. The steam and hot water piping in the occupied areas of the building are to remain. All steam traps located within the building will be replaced with new steam traps. The shell and tube heat exchangers, as well as their associated valving and piping, will be demolished. The existing loop pumps and their VFDs shall be demolished. The existing boiler's, feed water tank, and condensate collection tank shall be demolished. On the steam side, two (2) , fully redundant 4000 MBH steam boilers shall be installed. A new condensate collection tank with a new condensate pump to a newly installed feed water tank shall also be installed. This steam system will be responsible for taking care of the preheat coils located in MAU 1-4 and AHU-5. During periods where the outside air is warm, the steam system can be shutdown as required to save on energy.

On the hot water side, it is recommended that four (4) three thousand (3000) MBH condensing boilers with an output temperature setting of 130 degrees F be installed. The boilers would have a n+1 redundancy. The boilers would run on a factory programmed cascading system to maximize energy efficiency. This will be enough to cover all hot water heating coils within the building. Also, with smaller, more numerous boilers, there would be better turndown on the system. During times low reheat load, most of the boilers may remain off while one can carry the load. Because of the size of the system, a variable primary, variable secondary system is recommended with a decoupling link to connect the two loops. New, 600 gpm, 20 hp secondary pumps controlled by VFDs should be installed in place of the existing pumps. New primary pumps will also need to be installed as well to serve each boiler. All piping changes can be completed in the basement mechanical space, limiting the impact on the rest of the building. This system will be a compromise between options 2 and 3.

Option 2:

In this option, the 250 hp Burnham steam boilers will be replaced with like 250 hp steam boilers. With newer technologies, the turndown on the boilers should be greater. The feed tank has been replaced recently, meaning it can remain as it is sized for the existing steam boilers. The condensate collection tank shall be demolished and replaced as it is existing to the building. All steam traps will be replaced as well throughout the building. Most steam and condensate piping shall remain.

On the hot water side, the shell and tube steam to hot water heat exchangers will be upsized to meet the demand of the new reheat coils on the VBs and FVBs. The 1/3, 2/3 steam piping configuration shall stay as is. It is recommended that the leaving temperature of the water of the shell and tube be 180 deg F. The shell and tube heat exchanger shall transfer six thousand (6,000) MBH from the steam to the hot water. This will consume about six thousand (6,000) lbs/hr of steam. Two new 600 gpm, 20 hp variable speed loop pumps will be installed in place of the existing loop pump. This will require minimal piping adaptations to connect the new equipment into the system. Also, with an increase in reheat needs, the steam boiler should run on a higher setting than low fire. More hot water needs to be produced throughout the year, meaning more steam will be used.

Option 3:

It was identified during the initial facility walkthrough that MoDOT may be interested in removing the steam boilers within the building. While this is possible, the impact on the building will be great. New, main hot water piping will need to be routed throughout the building. This will cause major shutdowns over multi weeks, if not months, as piping is installed. Because of this, M/E1 recommends the steam system to remain in use. However, if MoDOT finds long shutdowns acceptable and would like to remove all steam piping within the building, this is M/E1's recommendation.

It is also recommended that a new, single, 8" hot water loop be installed in place of the existing reheat and AHU/MAU loop. This will require the existing two (2) hot water loops to be demolished. This will help to simplify pumping controls. For this system, it is recommended that three (3) five thousand (5000) MBH condensing boilers with an output temperature setting of 130 degrees F. These will be fully redundant boilers that will run on a factory programmed cascading system. This will be enough to cover all heating coils within the building. With more boilers, as stated above, the turndown would be greater, allowing for a more efficient system to be installed. Because of the size of the system, a variable primary, variable secondary system is recommended with a decoupling link to connect the two loops. New, 900 gpm, 40 hp secondary pumps controlled by VFDs should be installed in place of the existing pumps. New primary pumps will also need to be installed. New flue venting will be required as well as an acid neutralization system. This system will be the most invasive as well as the most expensive as it is a complete overhaul of the system.

Aggregate Lab, Geotechnical Lab, Cement Mixing Lab, Cement Lab, and Administration Equipment Replacement

This is a broad, wide range fix, but the aging equipment of these areas of the lab and improper design of the distribution system is causing comfort issues as well as the rusting of equipment in the aggregate area. These systems need to be upgraded to newer systems, air distribution to rooms need to be rebalanced to match the room needs, and controls and their sequences will need to be updated.

Aggregate Lab:

The aggregate lab is served by AHU-3. This air handler, like AHU-1 and AHU-2, and its systems have issues properly conditioning spaces. Space temperature setpoints are not able to be maintained. A new VAV air handler matching AHU-3's performance will need to be installed. The coils will be spread further apart for proper maintenance. This unit will have ventilation air. An outside air flow measuring station shall be installed to measure outside air incoming into the space. The existing FVBs and VBs will be replaced with new boxes. All boxes will have hot water reheat coils installed with them. New hot water piping will need to be extended over from the central hot water loop to the new VBs. The flow at the VBs and FVBs will be controlled by modulating two-way valves. New balancing valves will also be installed. Both the new FVBs and VBs can then heat the space. If two boxes serve communicating spaces, they should be twinned on one thermostat. This will make the space a true VAV system with reheat. This will allow the air handler to properly dehumidify the space while not over cooling the space.

Exhaust fans serving the space will be replaced with like for like exhaust fans. These fans will run constantly during occupied hours. This will allow the aggregate area to stay negative during the day. This will help keep contaminants from escaping the space. A pressure sensor across the door from the aggregate lab to the hallway will be installed to monitor pressure. The VFDs on the fans will ramp up and down to maintain the pressure differential setpoint.

Geotechnical Lab:

AHU-4 shall be replaced with a like for like unit. The coils shall be separated to allow for proper maintenance. This will be a true VAV type unit. The unit will distribute 55 deg F air to the supply ductwork. This unit will have ventilation air. An outside air flow measuring station shall be installed to measure outside air incoming into the space. The fan will modulate based on a duct static pressure sensor. The VBs and FVBs will be replaced with new boxes. New hot water piping will need to be extended over from the central hot water loop to the new VBs. .The flow at the VBs and FVBs will be controlled by modulating two-way valves. New balancing valves will also be installed. Both the new FVBs and VBs can then heat the space. If two boxes serve communicating spaces, they should be twinned on one thermostat. New offices have been added to the main room. A new VB shall be added to temper those new spaces that were not part of the original design. This will help with comfort for the employees in the office spaces.

Within the office spaces, the existing slot diffusers distribute air down onto employees. In the spaces with a lay-in ceiling, slots should be located on the perimeter of the building. Any diffusers located where occupants sit beneath shall be a four-way plaque diffuser. This will mitigate the problem of dumping cold air onto occupants.

The last item that is to change is to increase the duct drop size from the unit into the space and add sound lagging around the ductwork. These two changes will help mitigate the sound of the unit breaking into the space.

Cement Mixing Lab:

AHU-7 shall be replaced with a like for like unit. The unit will be built in pieces on site as it is located within the basement. The return fan that serves AHU-7 shall also be replaced with a like fan. The unit shall be a VAV type unit. It shall discharge 55 deg F air to the supply ductwork and the supply fan shall modulate the fan to satisfy the duct static pressure setpoint.

The FVBs and VBs that the AHU serves shall be replaced with new boxes. New hot water piping will need to be extended over from the central hot water loop to the new VBs. The flow at the VBs and FVBs would be controlled by modulating two-way valves. New balancing valves will also be installed. Both the new FVBs and VBs can then heat the space. If two boxes serve communicating spaces, they should be twinned on one thermostat. This should help with the conditioning of the spaces.

AHU-9 that serves the freeze thaw room shall be replaced. This unit can be downsized as the freeze thaw unit has recently been updated. The heat that the new unit outputs is marginal compared to older unit, meaning the required cooling is minimal. A transition curb shall be used to mount the AHU to the existing curb. The AHU shall be the secondary cooling while the FVB shall be the primary cooling source.

MAU-4 delivers make up air to the hoods in the cement mixing area. This unit shall be replaced with a like for like unit. The coils within the unit shall be separated to allow for proper maintenance. The preheat coils, the cooling coil, and reheat coil shall modulate to deliver dry, room neutral air to the supply ductwork.

The exhaust fans that serve the two (2) hoods in the cement mixing lab are to be replaced. Automatic dampers will be added at the base of the fan. These will open and close based on fan operation. This will block untampered air from falling into the space. Fume hood controllers will be added to the system to measure the sash height of the hood. This will then allow the VFD of the fan to vary the volumetric flow through the hood. A flow measuring system would measure the airflow. This will allow the CVB to modulate its damper to maintain a constant volumetric flow offset.

Cement Lab:

AHU-11 and AHU-12 are to be replaced with new, DX units. The existing duct humidifier shall remain. A duct, hot water heating coil shall be installed in the existing duct to allow for heating the supply air. Ductwork shall extended over to the window to wash down the window. It will help with keeping the window warm during the winter, mitigating the formation of condensation on the window.

Administration:

AHU-5 is currently a constant volume system. To upgrade the system, the air handler will become a single zone VAV system. The unit will stay the same capacity from a heating and cooling perspective; however, the unit will modulate the fan speed and reheat coil to maintain the space temperature of the hallway.

Exhaust fans that serve the spaces AHU-5 serves shall be replaced. The fans shall be installed with a motorized backdraft damper. Both the fan and damper shall be set on an occupied/unoccupied schedule for operation.

AHU-7 shall be replaced with a like for like unit. The unit will be built in pieces on site as it is located within the basement. The return fan that serves AHU-7 shall also be replaced with a like fan. The unit shall be a VAV type unit. It shall discharge 55 deg F air to the supply ductwork and the supply fan shall modulate the fan to satisfy the duct static pressure setpoint.

The FVBs and VBs that the AHU serves shall be replaced with new boxes. New hot water piping will need to be extended over from the central hot water loop to the new VBs. The flow at the VBs and FVBs will be controlled by modulating two-way valves. New balancing valves will also be installed. Both the new FVBs and VBs can then heat the space. If two boxes serve communicating spaces, they shall be twinned on one thermostat. This will help with the conditioning of the spaces. New zoning shall be considered as walls and uses of areas have changed over time.

COST ANALYSIS

CHEMICAL LAB OPTION 1

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Replacement of AHU-1	1	EA	$ 450,000	$ 450,000
Replacement of MAU-1	1	EA	$ 450,000	$ 450,000
Replacement of MAU-2	1	EA	$ 800,000	$ 800,000
Replacement of Lab Hooded Exhaust Fan	28	EA	$ 25,000	$ 700,000
Replacement of General Exhaust	4	EA	$ 10,000	$ 40,000
New Conrollers on hoods	28	EA	$ 200	$ 5,600
Adding Exhaust Fan	1	EA	$ 10,000	$ 10,000
Replacement of FVBs	6	EA	$ 4,500	$ 27,000
Replacement of VBs	10	EA	$ 1,500	$ 15,000
Replacement of CVBs	11	EA	$ 1,000	$ 11,000
Adding Volumetric Flow Measuring to hoods	27	EA	$ 2,000	$ 54,000
Adding hot water piping	300	FT	$ 75	$ 22,500
Adding new CVBs	2	EA	$ 2,500	$ 5,000
Adding Pressure sensors to the space	15	EA	$ 2,500	$ 37,500
Changing new air distribution	1	EA	$ 50,000	$ 50,000
Updated Controls and Sequences	1	EA	$ 200,000	$ 200,000
Electrical	1	EA	$ 100,000	$ 100,000

Total	$ 2,977,600

CHEMICAL LAB OPTION 2

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Demolition of Lab Area	1	EA	$ 200,000	$ 200,000
Replacement of MAU-1	1	EA	$ 450,000	$ 450,000
Replacement of MAU-2	1	EA	$ 800,000	$ 800,000
Partition to separate spaces	200	SF	$ 25	$ 5,000
New Installation of Doors	3	EA	$ 2,000	$ 6,000
New Hoods	10	EA	$ 20,000	$ 200,000
Smaller Lab Exhaust Fans	3	EA	$ 25,000	$ 75,000
Large Lab Exhaust Fans	4	EA	$ 100,000	$ 400,000
New Air Valves	25	EA	$ 12,500	$ 312,500
New Ductwork	400	EA	$ 200	$ 80,000
Diffusers, Grilles, Registers	100	EA	$ 250	$ 25,000
New Hot Water Piping	500	FT	$ 75	$ 37,500
New VAV boxes with Hot Water Reheat	16	EA	$ 1,500	$ 24,000
Adding Pressure sensors to the space	15	EA	$ 2,500	$ 37,500
Updated Controls and Sequences	1	EA	$ 350,000	$ 350,000
MAU-1 ERV	1	EA	$ 150,000	$ 150,000
MAU-2 ERV	1	EA	$ 425,000	$ 425,000
Electrical	1	EA	$ 450,000	$ 450,000
New Conrollers on hoods	28	EA	$ 200	$ 5,600

Total	$ 4,033,100

BITUMINOUS AND GENERAL MATERIAL LAB

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Replacement of AHU-2	1	EA	$ 450,000	$ 450,000
Replacement of MAU-3	1	EA	$ 450,000	$ 450,000
Replacement of VBs	13	EA	$ 1,500	$ 19,500
Replacement of CVBs	6	EA	$ 1,000	$ 6,000
Replacement of Lab Hooded Exhaust Fan	6	EA	$ 25,000	$ 150,000
Adding Pressure sensors to the space	6	EA	$ 2,500	$ 15,000
Adding hot water piping	200	FT	$ 75	$ 15,000
Changing new air distribution	1	EA	$ 35,000	$ 35,000
Updated Controls and Sequences	1	EA	$ 100,000	$ 100,000
Electrical	1	EA	$ 30,000	$ 30,000

Total	$ 1,270,500

CEMENT MIXING AND AGGREGATE

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Replacement Dust Collector	1	EA	$ 275,000	$ 275,000
Electrical	1	EA	$ 15,000	$ 15,000
New Safety Controls	1	EA	$ 30,000	$ 30,000
New Fan Filter Units	1	EA	$ 30,000	$ 30,000

Total	$ 350,000

BUILDING HEAT OPTION 1

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Demolition of Existing Hot Water System	1	EA	$ 150,000	$ 150,000
Replacement of Steam Traps	12	EA	$ 750	$ 9,000
Installation of New 4000 MBH steam boiler	2	EA	$ 160,000	$ 320,000
Installation of New 3000 MBH Hot Water Condensing boiler	4	EA	$ 145,000	$ 580,000
Installation of New Loop pumps (with piping Modifications)	2	EA	$ 65,000	$ 130,000
Installation of New primaray loop pumps (with piping modifications)	2	EA	$ 15,000	$ 30,000
Electrical	1	EA	$ 75,000	$ 75,000
Controls	1	EA	$ 45,000	$ 45,000.00

Total	$ 1,339,000

BUILDING HEAT OPTION 2

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Demolition of Existing Hot Water System	1	EA	$ 150,000	$ 150,000
Replacement of Steam Traps	12	EA	$ 750	$ 9,000
Replacement of 250 HP steam boiler	2	EA	$ 250,000	$ 500,000
Replacement of Loop Pumps	2	EA	$ 45,000	$ 90,000
Upsizing of Tube and Shell Heat Exchangers	2	EA	$ 85,000	$ 170,000
Electrical	1	EA	$ 40,000	$ 40,000
Controls	1	EA	$ 25,000	$ 25,000.00

Total	$ 984,000

BUILDING HEAT OPTION 3

Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Demolition of Existing Hot Water System	1	EA	$ 350,000	$ 350,000
Installation of New 5000 MBH Condensing Boilers	3	EA	$ 225,000	$ 675,000
New Hot Water Piping	1000	LF	$ 250	$ 250,000
New Loop Pumps	2	EA	$ 85,000	$ 170,000
New Primary Pumps	2	EA	$ 25,000	$ 50,000
New Flue Venting	200	LF	$ 200	$ 40,000
Electrical	1	EA	$ 125,000	$ 125,000
Controls	1	EA	$ 80,000	$ 80,000

Total	$ 1,740,000

OTHER UPGRADE COSTS

	Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Aggregate Lab	Replacement of AHU-3	1	EA	$ 450,000	$ 450,000
	Replacement of FVBs	5	EA	$ 4,500	$ 22,500
	Replacement of VBs	9	EA	$ 1,500	$ 13,500
	Replacement of Lab Exhaust Fans	3	EA	$ 25,000	$ 75,000
	Adding Pressure sensors to space	5	EA	$ 2,500	$ 12,500
	Hot Water Piping	200	LF	$ 75	$ 15,000
	Electrical	1	EA	$ 30,000	$ 30,000
	Controls	1	EA	$ 45,000	$ 45,000
				Total	$ 663,500
Geotechnical Lab	Replacement of AHU-4	1	EA	$ 325,000	$ 325,000
	Changes to air flow distribution	1	EA	$ 20,000	$ 20,000
	Increase in duct drop size	1	EA	$ 20,000	$ 20,000
	Replacement of FVBs	5	EA	$ 4,500	$ 22,500
	Replacement of VBs	4	EA	$ 1,500	$ 6,000
	Hot Water Piping	150	LF	$ 75	$ 11,250
	Electrical	1	EA	$ 25,000	$ 25,000
	Controls	1	EA	$ 30,000	$ 30,000
				Total	$ 459,750
Cement Mixing Lab	Replacement of AHU-7	1	EA	$ 175,000	$ 175,000
	Replacement of AHU-9	1	EA	$ 85,000	$ 85,000
	Replacement of MAU-4	1	EA	$ 225,000	$ 225,000
	Replacement of Lab Exhaust Fans	2	EA	$ 25,000	$ 50,000
	Replacement of FVBs	4	EA	$ 4,500	$ 18,000
	Replacement of VBs	5	EA	$ 1,500	$ 7,500
	Hot Water Piping	150	LF	$ 75	$ 11,250
	Replacement of CVBs	2	EA	$ 1,000	$ 2,000
	Electrical	1	EA	$ 45,000	$ 45,000
	Controls	1	EA	$ 60,000	$ 60,000
	Fume Hood Controls	2	EA	$ 200	$ 400
				Total	$ 679,150

OTHER UPGRADE COSTS

	Item Description	Quantity	Unit	Cost per Unit w/ Labor	Total
Cement Lab	Replacement of AHU-11	1	EA	$ 40,000	$ 40,000
	Replacement of AHU-12	1	EA	$ 40,000	$ 40,000
	Extending Ductwork to Window	1	EA	$ 20,000	$ 20,000
	New Hot Water Coil	1	EA	$ 2,500	$ 2,500
	Hot Water Piping	100	LF	$ 75	$ 7,500
	Electrical	1	EA	$ 10,000	$ 10,000
	Controls	1	EA	$ 15,000	$ 15,000
				Total	$ 135,000
Administration	Replacement of AHU-5	1	EA	$ 250,000	$ 250,000
	Replacement of AHU-7	1	EA	$ 150,000	$ 150,000
	Replacement of FVBs	11	EA	$ 4,500	$ 49,500
	Replacement of VBs	7	EA	$ 1,500	$ 10,500
	Hot Water Piping	200	LF	$ 75	$ 15,000
	Replacement of General Exhaust Fans	4	EA	$ 10,000	$ 40,000
	Electrical	1	EA	$ 45,000	$ 45,000
	Controls	1	EA	$ 55,000	$ 55,000
				Total	$ 615,000

Grand Total	$ 2,552,400

Estimate Summary

COST ESTIMATE SUMMARY WITH LEAST EXPENSIVE OPTIONS SELECTED

Chem Lab Option 1	$ 2,977,600	
Bituminous/General Material	$ 1,270,500	
Cement Mixing and Aggregate Dust Collection	$ 350,000	
Building Heat Option 1	$ 984,000	
OTHER UPGRADE COSTS	$ 2,552,400	
TOTAL DIRECT PROJECT COSTS		**$ 8,134,500**
CONTINGENCY		$ 406,725
BIDDING/ADMIN FEES		$ 203,363
A/E DESIGN FEES		$ 650,760
TOTAL SOFT COSTS		**$ 1,260,848**
TOTAL ESTIMATED PROJECT COST		**$ 9,395,348**

COST ESTIMATE SUMMARY WITH MOST EXPENSIVE OPTIONS SELECTED

Chem Lab Option 2	$ 4,033,100	
Bituminous/General Material	$ 1,270,500	
Cement Mixing and Aggregate Dust Collection	$ 350,000	
BUILDING HEAT OPTION 3	$ 1,740,000	
OTHER UPGRADE COSTS	$ 2,552,400	
TOTAL DIRECT PROJECT COSTS		**$ 9,946,000**
CONTINGENCY		$ 497,300
BIDDING/ADMIN FEES		$ 248,650
A/E DESIGN FEES		$ 795,680
TOTAL SOFT COSTS		**$ 1,541,630**
TOTAL ESTIMATED PROJECT COST		**$ 11,487,630**

CONCLUSION

The comprehensive HVAC upgrades at MoDOT's Central Laboratory represent a transformative initiative aimed at modernizing facilities, enhancing operational efficiency, and improving occupant comfort and safety. The conclusions drawn from this report underscore the significance of the HVAC upgrades and their impact on the overall functionality and sustainability of the laboratory environment.

The HVAC upgrades encompass a range of critical improvements, including the installation of state-of-the-art air handling units (AHUs), exhaust/ventilation system enhancements, controls upgrades, and ductwork/diffuser modifications. These upgrades address longstanding deficiencies in the existing HVAC infrastructure, promoting optimal air quality, thermal comfort, and energy efficiency throughout the facility.

Key highlights and outcomes of the HVAC upgrades include:

- Enhanced Indoor Air Quality: The implementation of modern AHUs and exhaust systems ensures improved air circulation and contaminant removal, safeguarding the health and well-being of laboratory occupants.
- Energy Efficiency: Controls upgrades and system optimizations contribute to reduced energy consumption, lowering operational costs and supporting sustainability goals.
- Operational Reliability: By investing in redundancy measures and system upgrades, the laboratory benefits from enhanced reliability and reduced downtime associated with HVAC malfunctions.
- Compliance and Safety: The HVAC upgrades align with regulatory standards and industry best practices, ensuring compliance with safety and environmental requirements.

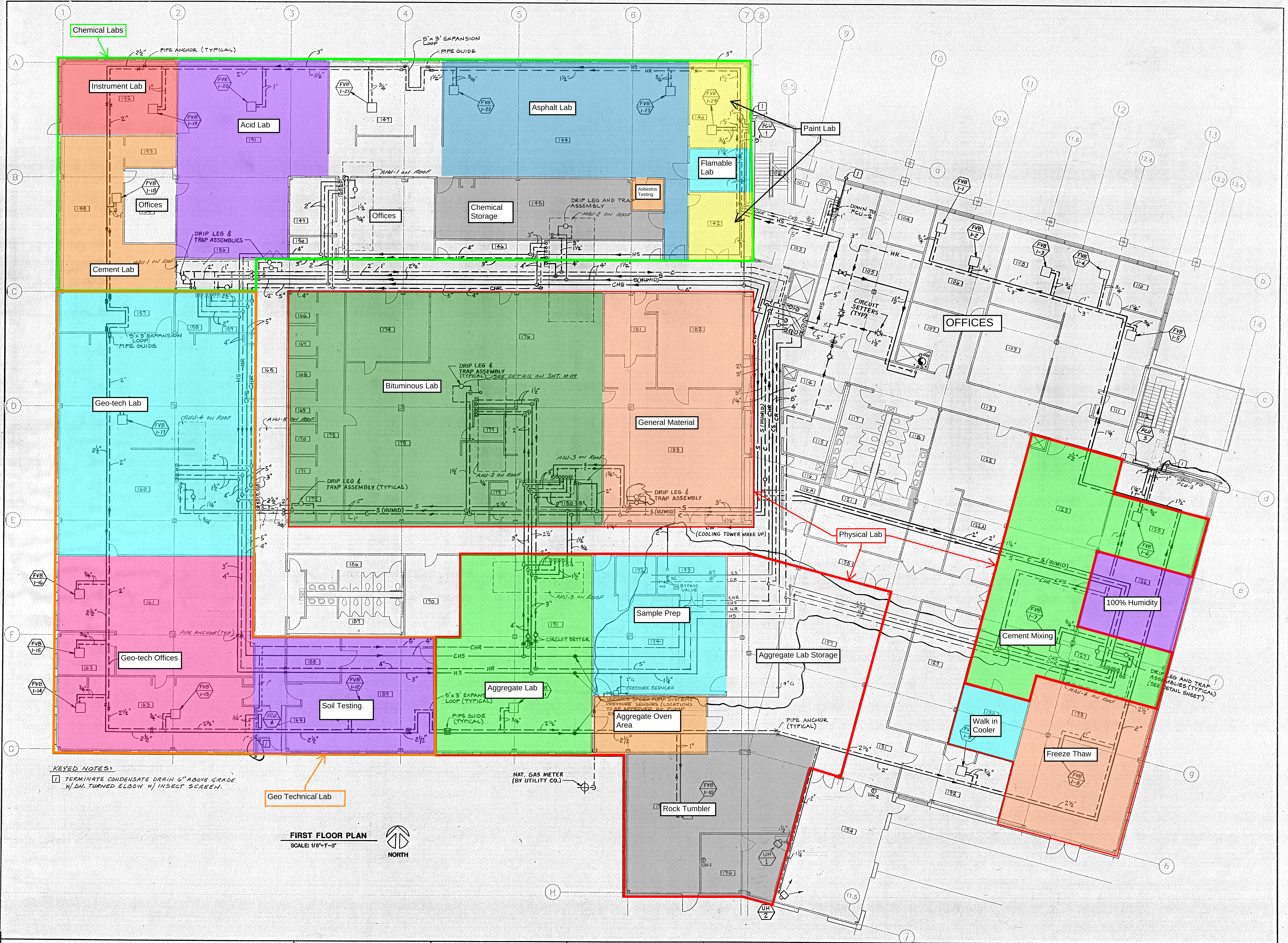
The budget allocation for the HVAC upgrades reflects strategic investment priorities, emphasizing cost efficiency and long-term value for MoDOT's Central Laboratory. The phased approach to implementation minimizes disruptions to ongoing operations and maximizes the effectiveness of upgrade efforts.

Looking ahead, the successful completion of the HVAC upgrades sets the stage for a more resilient, efficient, and sustainable laboratory environment, supporting MoDOT's mission of advancing transportation infrastructure and research excellence.

- Your Engineering Team at M/E1

APPENDIX 01

LAB ZONE KEY PLAN



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STATE OF MISSOURI
MEL CARNAHAN
GOVERNOR

OFFICE OF ADMINISTRATION
DIVISION OF DESIGN AND CONSTRUCTION
ROBERT W. WHITEHEAD P.E. ACTING DIRECTOR

MISSOURI HIGHWAYS AND TRANSPORTATION DEPARTMENT
WAYNE MURI CHIEF ENGINEER

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DATE: OCT. 30, 1992

GROUND FLOOR PLAN-PIPING

MATERIALS TESTING AND RESEARCH LABORATORY
JEFFERSON CITY, MISSOURI
FOR THE
MISSOURI HIGHWAYS AND TRANSPORTATION DEPARTMENT

229004501

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SHEET 51 OF 81

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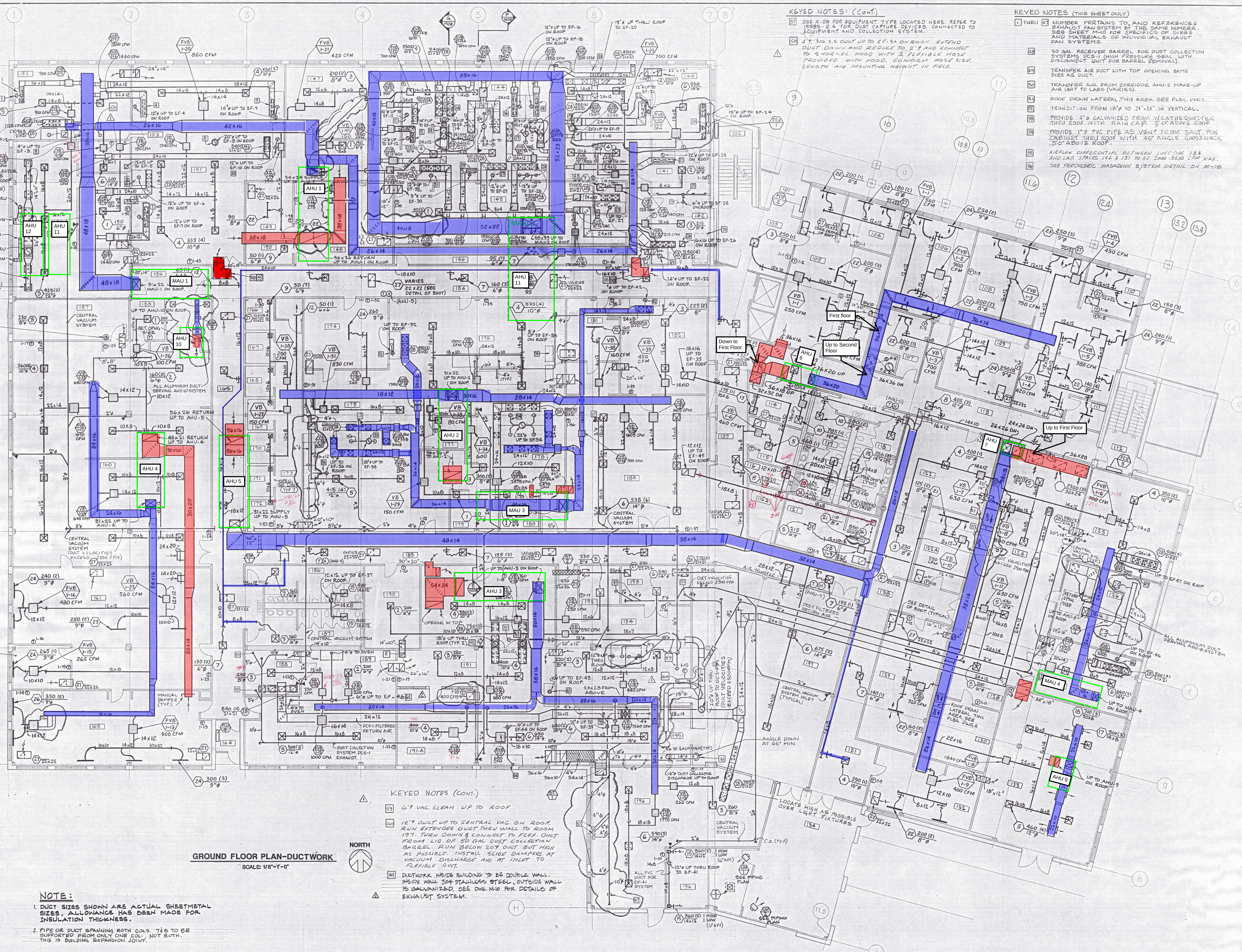
APPENDIX 02

EXISTING DUCT LAYOUT PLAN



GROUND FLOOR PLAN-DUCTWORK

SCALE: 1/8"=1'-0"

NORTH

KEYED NOTES: (CONT.)

[57] SEE A-28 FOR EQUIPMENT TYPE LOCATED HERE. REFER TO 15885-2.4 FOR DUST CAPTURE DEVICES CONNECTED TO EQUIPMENT AND COLLECTION SYSTEM.

[58] 4"Ø, 316 S.S. DUCT UP TO EF-3A ON ROOF. EXTEND DUCT DOWN AND REDUCE TO 2"Ø AND CONNECT TO SNORKEL HOOD WITH 2" FLEXIBLE HOSE PROVIDED WITH HOOD. CONFIRM HOSE SIZE, LENGTH AND MOUNTING HEIGHT IN FIELD.

KEYED NOTES (THIS SHEET ONLY)

[1] THRU [47] NUMBER PERTAINS TO, AND REFERENCES EXHAUST FAN SYSTEM BY THE SAME NUMBER. SEE SHEET M-10 FOR SPECIFICS OF SIZES AND MATERIALS OF INDIVIDUAL EXHAUST FAN SYSTEMS.

[48] 50 GAL. RECEIVER BARREL FOR DUST COLLECTION SYSTEMS DCS-1 (HIGH PRESSURE SEAL WITH DISCONNECT UNIT FOR BARREL REMOVAL).

[49] TRANSFER AIR DUCT WITH TOP OPENING SAME SIZE AS DUCT.

[50] TRANSFER AIR FROM CORRIDOR AHU-5 MAKE-UP AIR UNIT TO LABS (VARIES).

[51] ROOF DRAIN LATERAL THIS AREA. SEE PLBG. DWGS.

[52] TRANSITION FROM 18"Ø TO 24"x24" IN VERTICAL.

[53] PROVIDE 4"Ø GALVANIZED FROM WEATHEROMETER THRU ROOF WITH RAIN CAP. 3'-0" ABOVE ROOF

[54] PROVIDE 1"Ø PVC PIPE AS VENT FROM SALT FOG CABINET THRU ROOF WITH 45° ANGLE GOOSENECK 3'-0" ABOVE ROOF.

[55] AIRFLOW DIFFERENTIAL BETWEEN CORRIDOR 184 AND LAB SPACES 144 & 151 TO BE 2000-3500 CFM MAX.

[56] SEE PERCHLORIC WASHDOWN SYSTEM DETAIL ON M-08

KEYED NOTES (CONT.)

[59] 6"Ø VAC. CLEAN UP TO ROOF

[60] 12"Ø DUCT UP TO CENTRAL VAC. ON ROOF. RUN EXTENDED DUCT THRU WALL TO ROOM 197. TURN DOWN & CONNECT TO FLEX. DUCT FROM LID OF 50 GAL DUST COLLECTION BARREL. RUN BELOW 20"Ø DUCT BUT HIGH AS POSSIBLE. INSTALL SLIDE DAMPERS AT VACUUM DISCHARGE AND AT INLET TO FLEXIBLE DUCT.

[61] DUCTWORK INSIDE BUILDING TO BE DOUBLE WALL. INSIDE WALL 304 STAINLESS STEEL, OUTSIDE WALL IS GALVANIZED. SEE DWG. M-10 FOR DETAILS OF EXHAUST SYSTEM.

NOTE:

1. DUCT SIZES SHOWN ARE ACTUAL SHEETMETAL SIZES. ALLOWANCE HAS BEEN MADE FOR INSULATION THICKNESS.
2. PIPE OR DUCT SPANNING BOTH COLS. 7 & 8 TO BE SUPPORTED FROM ONLY ONE COL., NOT BOTH. THIS IS BUILDING EXPANSION JOINT.

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DATE OCT. 30, 1992
REVISED
DESIGNED BY CSC
DRAWN BY JN
CHECKED BY

SHEET TITLE
GROUND FLOOR PLAN-DUCTWORK

MATERIALS TESTING AND RESEARCH LABORATORY
JEFFERSON CITY, MISSOURI
FOR THE
MISSOURI HIGHWAYS AND TRANSPORTATION DEPARTMENT

PROJECT NO.: 07-605-91-0001(B) ACCOUNT NO.: 605-69187-9551, 605-06729-0672

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M-03

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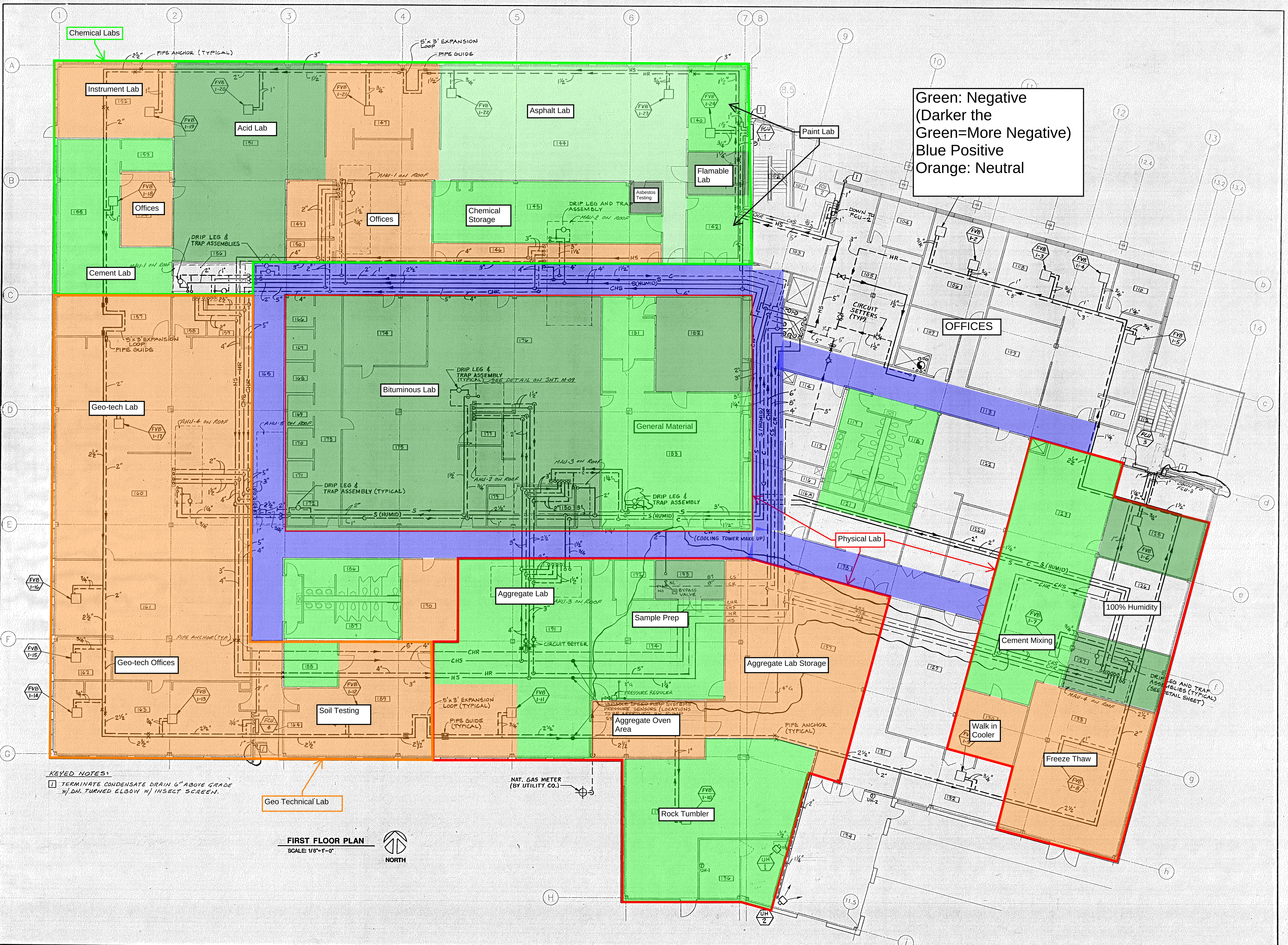
APPENDIX 03

PRESSURE RELATIONSHIP PLAN



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STATE OF MISSOURI — CREASON CRAIG STEPHEN NUMBER E-020362 — REGISTERED PROFESSIONAL ENGINEER — 7/14/93

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